THE MEASUREMENT OF KINETIC VARIABLES IN RACE WALKING

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The purpose of this study was to measure kinetic variables during race walking. Forty national and international race walkers walked either 5 km or 10 km at a pace equivalent to 105% of their season's best time. Junior athletes walked 5 km, while senior athletes (mostly 20 km walkers) walked 10 km. Kinetic data were collected using a Gaitway treadmill (1000 Hz). Data were collected at the 2.5 km point. Men had longer step lengths than women and walked faster as a result. There was little difference in cadence. Average flight times for each group of athlete were approximately 0.04 s. Senior athletes showed more 'typical' race walking vertical force patterns than the juniors; this may be linked to quantity of training experience and gait efficiency. Athletes are advised to develop muscular strength endurance to cope with loading rates upon initial contact.

KEY WORDS: race walking, force, athletics, treadmill.

INTRODUCTION: Previous research in race walking has predominantly focussed on kinematic data without reference to ground reaction forces (GRF). Payne (1978) measured the GRF for one international race walker and found that mediolateral forces were much greater than in normal walking with only small increases in vertical and anterioposterior forces. Fenton (1984) conducted studies on seven athletes of varying ability. Lower vertical impact peaks occurred in elite athletes compared to less skilled walkers. A second, weight-bearing peak then occurred, and a much smaller decrease in force to the point of midstance compared to normal walking. The final propulsive peak was smaller in race walking compared to normal walking as a proportion of the first peak (in race walking the push-off peak was approximately 0.5 BW below the weight-bearing peak). A limitation of measuring kinetic data by means of in-dwelling force plates is the difficulty with which multiple meaningful trials are possible. The accuracy of data collection can be affected by athletes targeting the force plates rather than walking naturally and ensuring that athletes walk at an appropriate, realistic pace. To combat this, Ávila *et al*. (1998) used a treadmill with in-built force plates (Gaitway, Traunstein) to compare normal walking GRFs with those in race walking; the four female athletes tended to display less variability in vertical forces when race walking. Neumann, Krug & Gohlitz (2008) used a similar treadmill to analyse four junior female race walkers at multiple points during a 6 and a 10 km walk, and found that the coefficient of variation for temporal variables tended to increase with distance walked. These studies focussed particularly on variability and not the importance of the kinetic parameters to race walking per se. Kinetic data collection has thus been negligible resulting in a lack of understanding of the mechanisms behind important kinematic parameters, particularly in women and junior athletes. The purpose of this study was to measure and provide a description of kinetic variables in male and female junior and senior race walkers.

METHODS: Data collection: Forty national and international race walkers gave informed consent and the study was approved by the university's ethics committee. The group of forty athletes comprised fifteen senior men (both 20 km and 50 km walkers), seven senior women, ten junior men, and eight junior women. The senior men had a mean age of 31 yrs (± 11), stature 1.81 m (± .08), and mass 72 kg (± 7). The senior women had a mean age of 26 yrs (± 7), stature 1.67 m (± .03), and mass 56 kg (± 8). The ten junior men had a mean age of 17 yrs (± 1), stature 1.80 m (± .06), and mass 65 kg (± 11) and the eight junior women had a mean age of 16 yrs (± 1), stature 1.67 m (± .04), and mass 56 kg (± 4). All participants were free from injury. Each senior athlete walked for 10 km on a treadmill (Gaitway, Traunstein) at a pace that resulted in a walking time equivalent to 105% (± 2) of their season's best time. Junior athletes who normally raced over 10 km walked on the treadmill for 5 km. Each athlete walked at a constant pace for the duration of the test. Kinetic data were recorded using the Gaitway treadmill, which has two in-dwelling force plates (Kistler, Winterthur). The sampling rate was 1000 Hz. Data were collected for thirty seconds at 2.5 km. As well as kinetic data, the associated software (Gaitway, Traunstein) gave values for step length, cadence, and temporal data.

Data analysis: Because of low sample sizes for each specific age and gender group, Pearson's product moment correlation coefficient was used to find associations within all male walkers (N = 25) and all female walkers (N = 15). Comparisons between groups (using one-way ANOVA) have not been undertaken due to the small sample sizes per group.

RESULTS: Table 1 shows the mean values of speed, step length and cadence for each group of athletes. The overall range of values for step length was from 0.96 m to 1.22 m for men, and from 0.93 m to 1.09 m for women. With regard to cadence, the overall range was from 2.80 to 3.37 Hz for men, and from 3.00 to 3.26 Hz for women. The mean step length value is also shown expressed as a percentage of the athletes' statures. It can be seen that in general, athletes had step lengths measuring approximately 60% of their standing heights. Walking speed is the product of step frequency (cadence) and step length. In both male and female groups, speed was positively correlated with step length when expressed in both absolute (m) and relative terms (%) (p < .01). Men's standing height was positively correlated with step length (p < .01) and negatively with cadence (p < .01). No significant correlations with stature were found in the women athletes. Speed was correlated with cadence in the men's group (p < .05) but not the women's (p = .10).

Table 1 Speed, step length, and cadence data for each group (mean ± SD)

	Speed (km/hr)	Step length (m)	Step length (%)	Cadence (Hz)
Senior men	12.74 (± 0.64)	1.13 (± 0.08)	62.2 (± 3.4)	3.13 (± 0.15)
Senior women	11.59 (± 0.58)	1.01 (± 0.05)	60.8 (± 2.9)	3.17 (± 0.07)
Junior men	11.99 (± 0.85)	1.09 (± 0.06)	60.6 (± 2.5)	3.05 (± 0.18)
Junior women	11.08 (± 0.56)	1.00 (± 0.05)	59.9 (± 3.1)	3.08 (± 0.05)

Cadence is determined by the time taken to complete each successive step; the shorter the step time, the higher the cadence. In turn, step time can be broken down into two components: contact time and flight time. The values for each of these variables, as well as the percentage of step time spent in contact, are shown in Table 2. Similarly to cadence in Table 1, there are only small differences between groups for step time values. Although strictly speaking there should be no flight time in race walking because of IAAF rule 230.1, most groups in this study had flight times of approximately 0.04 s, with junior women having flight times of 0.05 s. Flight time and contact time were negatively correlated with each other (p < .01). Within the male athletes, both step time and contact time were negatively correlated with speed (p < .05 and p < .01 respectively) and flight time was positively correlated with speed (p < .05). In the women walkers, only contact time showed a (negative) correlation with speed (p < .05). Flight time was positively correlated with step length in both male and female groups (p < .05). The negative correlation found between men's heights and cadence was more related to their contact times (p = .06) rather than to their flight times (p = .87).

Table 2 Step time, contact time, and flight time data for each group (mean ± SD)

	Step time (s)	Contact time (s)	Flight time (s)	Contact time (%)
Senior men	0.32 (± 0.02)	0.28 (± 0.02)	0.04 (± 0.02)	87.9 (± 4.7)
Senior women	0.32 (± 0.01)	0.28 (± 0.02)	0.04 (± 0.01)	87.1 (± 4.3)
Junior men	0.33 (± 0.02)	0.29 (± 0.03)	0.04 (± 0.01)	87.9 (± 4.8)
Junior women	0.33 (± 0.01)	0.27 (± 0.01)	0.05 (± 0.01)	84.3 (± 3.3)

Table 3 shows the forces at the impact, first (loading), midsupport and active (push-off) peaks. Impact peak was defined as the highest recorded force during the first 70 ms of contact with the treadmill; midsupport force was defined as the minimum force value recorded between the first and second peak forces. Only vertical ground reaction forces are displayed as it is not possible to record shear forces with the treadmill. All forces are shown as normalised data. The only correlations found between these data and speed was a positive correlation with midsupport force in men (p < .05) and with first peak force in women (p < .01). Furthermore, step length was also correlated with first peak force in women (p < .05) and cadence with second peak force in women (p < .05). Contact time was negatively correlated with both first peak force and midsupport force in both groups of athletes (p < .05 for men and p < .01 for women). In addition, flight time was positively correlated with first peak, midsupport, and second peak forces in both groups (p < .01 for men and p < .05 for women).

Table 3 Force data for each group (mean ± SD)

	Impact peak (BW)	First peak force (BW)	Midsupport force (BW)	Second peak force (BW)
Senior men	1.48 (± 0.21)	1.77 (± 0.13)	1.30 (± 0.28)	1.57 (± 0.11)
Senior women	1.56 (± 0.21)	1.80 (± 0.19)	1.41 (± 0.32)	1.55 (± 0.10)
Junior men	1.40 (± 0.18)	1.79 (± 0.10)	1.36 (± 0.28)	1.61 (± 0.09)
Junior women	1.56 (± 0.19)	1.73 (± 0.11)	1.34 (± 0.20)	1.68 (± 0.05)

Weight acceptance is the slope of the force curve during the loading phase, taken from the point of 10% of the impact peak force to the point of 90%; while the push-off rate is the slope of the force curve during unloading, taken from the point of 90% of push-off peak force to the point of 10%. Impulse was recorded in the vertical direction, while base of support is the average distance between one foot's mediolateral centre of pressure and the next opposing foot's mediolateral centre of pressure for each foot strike. Table 4 shows the results for these variables. In women, impulse was negatively correlated with weight acceptance rate (p < .01) and positively with push-off rate (p < .05). In men, there was a positive correlation between base of support and weight acceptance rate (p < .05) and a negative one between base of support and midsupport force (p < .05). Impulse was negatively correlated with speed in the men's group (p < .05).

Table 4 Loading rates, impulse, and base of support for each group (mean ± SD)

	Wt. Acceptance (BW/s)	Push-off rate (BW/s)	Impulse (BW.s)	Base of support (mm)
Senior men	29.4 (± 5.5)	16.1 (± 3.9)	0.32 (± 0.02)	37 (± 23)
Senior women	32.0 (± 5.9)	15.1 (± 3.2)	0.31 (± 0.01)	44 (± 18)
Junior men	30.8 (± 4.8)	13.3 (± 2.8)	0.33 (± 0.02)	30 (± 11)
Junior women	30.8 (± 4.5)	18.9 (± 3.6)	0.32 (± 0.01)	28 (± 13)

DISCUSSION: Both male groups were faster than the female groups and this was predominantly due to their longer step lengths. Very little difference was found between men and women for cadence values, although it could be assumed that faster walkers will have a balanced combination of both long step lengths and high walking cadences. One important factor for athletes and coaches to consider is the length of the athletes' stride in relation to their overall standing height. Consideration of this will allow for better comparison with other walkers.

Both groups of senior athletes had slightly shorter step times compared to the junior athletes, and the junior women had slightly longer flight times at 0.05 s. It is unlikely that this duration of flight (or the 0.04 s duration for other groups) would be visible to the naked eye when judging. Nonetheless, such flight times should be minimised as much as possible in order to adhere to the rules of the event and reduce the risk of disqualification.

The impact peaks for both senior and junior men were lower compared to both groups of women. This may suggest that the male athletes were more skilled than the females, as suggested by Fenton (1984). The men had an overall greater mean age and this may reflect more training experience. Midsupport forces in normal walking tend to drop below 1 BW; a range between 1.30 and 1.46 BW was found here. Furthermore, all groups had lower propulsive peak values than loading peaks, although the largest decrease was 0.25 BW. This value is less than that found by Fenton (1984) who found a 0.5 BW decrease, but the overall vertical force pattern suggested by him was mostly replicated here. The junior women showed the smallest decrease between these two values, and this may be a result of their relative inexperience in the event. Both groups of senior athletes showed relatively typical race walking GRF patterns.

All four groups of athletes had similar weight acceptance rates (approximately 30 BW/s); these values show the large loading rates experienced by the race walkers upon initial contact and the need for preventive exercises to prevent injury, particularly in the lower leg. Push-off rate was highest in the junior women although it must be remembered that this was a vertical force and therefore not necessarily conducive to forward propulsion.

A limitation of using the Gaitway treadmill is its inability to record shear forces; thus it is not possible to measure important variables which may be important (e.g. propulsive anterio-posterior forces). Although most athletes were experienced at walking on treadmills, it is an artificial setting in comparison with track or road walking and therefore it is not certain that the athletes adopted their normal walkign technique. Further studies investigating the validity of using treadmills to analyse race walking are warranted.

CONCLUSION: The pattern of vertical GRF in race walkers differs from normal walking in an attempt to maintain high speeds and prevent lifting of the centre of mass. Typical race walking patterns are not shown in less-experienced junior athletes. Coaches and athletes are advised to develop muscular endurance and work towards developing efficient race walking gait in order to develop efficiency of movement and reduce the risk of disqualification due to lifting.

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